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ABSTRACT

While a number of systems have been developed based on cognitive styles, and a significant body of research has been carried out about learning with multiple representations, little is known about the effectiveness of systems based on multiple intelligences (MI). To address this, a prototype was built based on Gardner's theory of MI and experiments were performed to study the effectiveness of the system on medical students' learning. The results showed that medical students accomplish deeper understanding of a topic when it is taught in a way that matches their cognitive styles. Moreover, the results indicated that providing students with a rich environment in which they can learn a topic via their chosen modality seems not to be as an effective teaching method as automatically adapting the material. (Author)

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Cognitive Styles and Medical Students' Learning

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Abstract: Whilst a number of systems have been developed based on cognitive styles, and a significant body of research has been carried about learning with multiple representations, little was known about the effectiveness of systems based on multiple intelligences (MI). To address this, a prototype was built based on Gardner's theory of multiple intelligences and experiments were performed to study the effectiveness of the system on medical students' learning. The results showed that medical students accomplish deeper understanding of a topic when it is taught in a way that matches their cognitive styles. Moreover, the results indicated that providing students with a rich environment in which they can learn a topic via their chosen modality seems not to be as an effective teaching method as automatically adapting the material.

Introduction

The Interactive Medical Library (IML) prototype is a multimedia library in Medicine that adapts to learners' cognitive styles (AlRawahi, 1999). The IML act as a database which contains a large amount of information such as medical images, digital videos, textual information, laboratory data, etc. The Interactive Medical Library attempts to be a source of information that learners can return to whenever they need to confirm their understanding or to review and study certain medical material.

The design of the IML prototype was influenced by Gardner theory of Multiple Intelligences. In his multiple intelligences (MI) theory Gardner in 1983 claims that every cultural role requires a combination of different abilities regardless of the sophistication. He considers a person's mind as a collection of more than one intelligence or ability. He categorized the following kinds of intelligence: Linguistic, Logical-Mathematical, Spatial, Musical, Bodily-Kinesthetic, Interpersonal, Intrapersonal and Natural. They work together depending on the problem to be solved, within the limitations imposed by the individual environment. Some activities require the higher progress of a single intelligence, while others require development in more than one practice (Gardner, 1993a). According to Gardner "Nearly all cultural roles exploit more than one intelligence; at the same time, no performance can come about simply through the exercise of a single intelligence."(Gardner, 1993b p.27)

Thus, the aim of this paper is to examine the effectiveness of a multimedia system (Interactive Medical Library prototype) that supports cognitive styles based on the theory of Multiple Intelligences in medical students' learning.

Method

Subjects

The subjects were 44 medical students in their fifth year of medical training from the Sultan Qaboos University (Oman). The subjects were randomly divided into four study groups according to the learning environment that they were given in the hypermedia library of the Hospital Round prototype.

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Procedure

The medical students were divided into four study groups. These groups were a Cognitive Style group, an Opposite to Cognitive Style group, a Traditional group and a Modality group. The Cognitive Style group was given material to study in keeping with their learning styles. The opposite to Cognitive Style group was given material to study opposite to their learning styles. The Traditional group was given material in various representations according to the method used in traditional teaching. Finally, the Multiple Representation or the Modality group could choose the modality they wished to learn with from a number of representations.

All subjects were given the Multiple Intelligences Developmental Assessment Scale (Shearer, 1996) questionnaire to fill out and they were asked to return the questionnaire and to come for the rest of the experiment on the following day. On the experiment day, the subjects were initially given the United States Medical Licensing Examination (USMLE) - step 1 to solve as a pre-test. After solving the pre-test questions each subject was given a demonstration about how to work with the computer using the Virtual Hospital Round Prototype. The subjects were then asked to work with a clinical case in the Cyber-Round individually. The cases in the Cyber-Round varied, some cases were relevant to the material in the library and other cases were not relevant to the material in the library. After working with a case, the subjects had to read 1-2 pages of medical material from the hypermedia library. Furthermore, according to the group the material that was given was:

a) according to their cognitive styles,
b) opposite of their cognitive styles,
c) according to the traditional way of teaching the topic, or
d) by using modality choices.

Soon afterwards, the subjects were given another clinical case to solve. Lastly, the subjects were given the USMLE post-test. The experimental structure is in Appendix I.

Hypotheses

The hypothesis was that students who were to be given material that adapted to their cognitive styles would do much better in understanding the medical material than all the other groups. In contrast, students who were to be given material opposite to their cognitive style their performance would do worse than all the other groups. While students who were to be assigned to a multiple modality group would outperform the students in the traditional group.

Testing Students' Medical Knowledge

The United States Medical Licensing Examination (USMLE) was used to test medical students' medical knowledge. This test is one of the standardised types of test normally used by various medical schools and testing authorities to test medical students and clinicians. The USMLE comes in three versions: Step 1, for medical knowledge, applicable for testing undergraduate medical students; Step 2, for resident and graduate students, who have just finished their clinical training; Lastly, Step 3 for clinicians who have some years of work experience. We used the Exam Master software product of the Exam Master Corporation to administer this test to our subjects. The Exam Master software allows the user to select certain topics to be examined in.

Since, our IML prototype focuses on Cardiovascular diseases, we selected for the test the subject of cardiovascular diseases and mainly the diseases of blood vessels and heart. This test contains 15 multiple choices questions. All subjects were given the same medical knowledge test twice, as a pre-test and then as a post-test. The first test was before working with the IML prototype and the second test was when they had finished working on all the activities of the prototype. The order of questions in the test was different in the pre-test and post-test. The function of these tests is to give us an idea about students' medical knowledge prior and after working with the Virtual Hospital Round Prototype. This test is described in Appendix II.

Structuring the learning representation

This section discusses the type of intelligences comprised in each group and the corresponding representations in the IML. The construction of different intelligence profiles in the IML involves a blend of various intelligences. These combinations are:

Profile 1: Visual > Linguistic > Musical;
Profile 2: Linguistic > Visual > Musical;
Profile 3: Linguistic > Musical > Visual,
Profile 4: Visual > Musical > Linguistic.

The profile (Visual > Linguistic > Musical) means that a student has a high visual, medium linguistic and low musical intelligence. Some students exhibited a slightly different profile such as *Visual = Linguistic > Musical; Visual > Linguistic = Musical; or Musical = Linguistic > Visual*. In order to verify the type of students' intelligences we used students' study habits and preferences as a second measure. Medical students' study preferences were gathered - by asking students about what do they think their preferences are - to verify weather the MIDAS profile matched the students' study preferences. These were included in the previous combination.

As mentioned earlier the Cognitive Style group were given representations that adapted to their intelligence profile, whilst the Opposite to the Cognitive Style group were given representations opposite to their intelligence profile. MIDAS profiles and the representations given in the hypermedia library of the IML are shown in Table 1 below. All the students in the Traditional group were given a mixed type of representation similar to the one used in conventional teaching. All the students in the Modality group were given multiple representations to choose from. The students in this group selected a representation according to their preferences.

	Multiple Intelligences Profile	Representation given in the IML
CS	*I. Visual > linguistic > musical* *II. Linguistic > visual > musical* *III. Linguistic > musical > visual* *IV. Visual > musical > linguistic*	*I. Visual > linguistic > musical* *II. Linguistic > visual > musical* *III. Linguistic > musical > visual* *IV. Visual > musical > linguistic*
OCS	*I. Visual > linguistic > musical* *II. Linguistic > visual > musical* *III. Linguistic > musical > visual* *IV. Visual > musical > linguistic*	*III. Linguistic > musical > visual* *IV. Visual > musical > linguistic* *I. Visual > linguistic > musical* *II. Linguistic > visual > musical*

Table 1. Categorization of the learning environment in the Cognitive Style group and the Opposite to the Cognitive Style group.

The numbers of subjects in the four groups were as follows:

CS	Cognitive Style Group(n=12)
OCS	Opposite to Cognitive Style Group(n=12)
TRAD	Traditional Group (n=10)
MR	Modality Group(n=10)

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Results

Learning Modality and Individual Competence

The results of USMLE

The means and standard deviations of students' correct answer out of 15 questions in each learning environment are presented in Table 2 below.

	CS	OCS	TRAD	MR	Overall
Pre-Test	6.58 (1.56)	6.75 (1.71)	5.80 (2.15)	6.20 (1.75)	6.36 (1.77)
Post-Test	10.67 (2.06)	8.08 (1.31)	8.60 (1.78)	8.40 (1.90)	8.98 (2.02)

Table 2. Mean (standard deviation) of students' correct answers out of 15 questions in each learning environment.

	CS	OCS	TRAD	MR	Overall
Pre-Test	43.89 (10.43)	45 (11.41)	38.67 (14.33)	41.33 (11.67)	42.4 (11.8)
Post-Test	71.11 (13.73)	53.89 (8.74)	57.33 (11.84)	56 (12.65)	59.87 (13.47)

Table 3. Mean(standard deviation) of students' percentage of correct answers in each learning environment.

There was a gain from pre-test to post-test for each of the four learning environments. The mean gain for the cognitive style group was greater than all the other three groups (percentage gain is 27.22). In contrast, the mean gain for the opposite to the cognitive style group was worse than all the other three groups (percentage gain is 8.89). The percentage gain in the traditional group and in the modality group are 18.67 and 16.67 respectively. The graph below presents the USMLE pre-test and post-test results for the four learning environments.

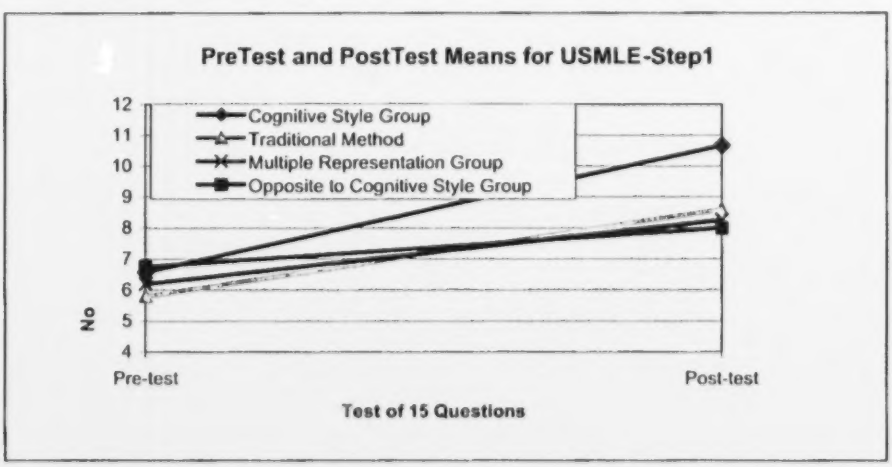

Figure 1. The result of USMLE pre/post tests in different learning environments.

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A one way analysis of variance (ANOVA) was performed to see if there was any significant variation between the results of different learning environment groups in the pre-test and post-test. Table4 shows the between groups and the within groups differences.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
PreTest	Between Groups	5.815	3	1.938	.604	.616
	Within Groups	128.367	40	3.209		
	Total	134.182	43			
PostTest	Between Groups	48.594	3	16.198	5.127	.004
	Within Groups	126.383	40	3.160		
	Total	174.977	43			

Table 4. ANOVA results of the pre-test and the post-test

The results of the ANOVA shows that there was a significant difference between different groups in the post-test F (3,40) =5.127; P = 0.004, and no significant differences between groups in the pre-test F (3,40) =.604; P = 0.616.

To get a more detailed understanding of what caused the differences in groups in the post- test to be significant, we performed Tukey HSD Post-hoc test. The post-hoc test showed there was a significant difference between the Cognitive Style group and all other groups in the post-test, but there were no significant differences between the other three groups.

The significant difference in post-test score between the Cognitive Style group and the Opposite to the cognitive style group was 2.58, (p = 0.005) See Table 9.2. The significant difference between the Cognitive Style group and the Traditional group was 2.07, (p = 0.046), and between the Cognitive Style group and the Modality group was 2.27, (p = 0.024). This result means that the cognitive style group benefited more than all the other three groups. On that account, teaching students in an environment that adapts to their cognitive style seems to help them to grasp the material more easily.

Time spent on the Library

The mean time (in minutes) that each group of students spent on the library is presented in Table 4 below.

Modality	Time (min.)	% Gain in test	No. pages viewed	Viewing time/page(min.)
CS	11.13 (2.80)	27.22 % (8.27)	4.58 (0.51)	2.43
OCS	11.01 (4.20)	8.89 % (12.50)	4.75 (0.45)	2.32
TRAD	12.45 (2.75)	18.67 % (7.57)	4.60 (0.52)	2.71
MR	15.26 (3.37)	14.67 % (7.57)	10.00 (2.83)	1.53
Overall	12.34	17.36	5.98	2.25

Table 5. Mean time in minute that students spent on the library, mean gain in test and mean number of pages viewed.

From Table 5 and Figure 3, it seems that students in the Modality group (MR) spent a much longer time using the IML (t = 15.26 min) than all other groups. However, the performance of this group was much less than the

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performance of the Cognitive Style group. This Modality (MR) group viewed almost double the number of pages. The average amount of time MR students spent viewing a page was 1.53 minutes. This time was much less than the average amount of time students spent viewing pages in the other learning environments.

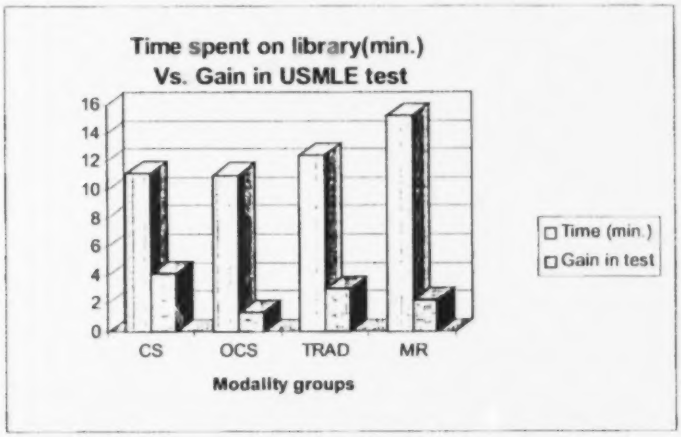

Figure 2. Time spent on library vs. gain in test in different learning environments.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
PreTest	Between Groups	5.815	3	1.938	.604	.616
	Within Groups	128.367	40	3.209		
	Total	134.182	43			
PostTest	Between Groups	48.594	3	16.198	5.127	.004
	Within Groups	126.383	40	3.160		
	Total	174.977	43			
LIBTIME	Between Groups	124.049	3	41.350	3.676	.020
	Within Groups	449.895	40	11.247		
	Total	573.944	43			
Posttest-pretest	Between Groups	48.703	3	16.234	8.201	.000
	Within Groups	79.183	40	1.980		
	Total	127.886	43			

Table 6. One way ANOVA of USMLE tests and library time.

The results of the one way ANOVA in Table 6 shows that there was a significant difference in time spent on the library between the different groups $F(3,40) = 3.676$, $p = .020$. A Tukey HSD Post-hoc analysis was performed. This showed that there were significant differences in the amount of time students spent reading the material in the library between the Modality group and Cognitive Style group (Mean difference = 4.13 mins., $p = 0.032$), and also between the Modality group and the Opposite to the Cognitive Style group (Mean difference = 4.25 mins., $p = 0.025$).

Gain in test, amount of information viewed and time spent on Library

The ANOVA also shows there is a significant difference in the gain in the USMLE test (Post Test - Pre Test) between different modality groups $F(3,40) = 8.201$, $p < .001$. A Tukey HSD post hoc test shows that there is a significant difference in the amount of gain in the test between the Cognitive Style group and the Opposite to the Cognitive Style group (Mean difference = 2.75, $p < 0.001$), and between the Cognitive Style group and the Modality group (Mean difference = 1.89, $p = 0.017$), and also between the Traditional group and the Opposite to the Cognitive Style group (Mean difference = 1.67, $p = 0.041$).

Moreover, the ANOVA shows that there is a significant difference in the amount of information viewed by different groups $F(3,40) = 37.14$, $p < 0.001$. A Tukey HSD post hoc test shows that there are significant differences on the number of pages viewed between the Modality group and all other groups.

- The Modality group and the Cognitive Style group; Mean difference = 5.42, $p < 0.001$
- The Modality group and the Opposite to the Cognitive Style group; Mean difference = 5.25, $p < 0.001$
- The Modality group and the Traditional group; Mean difference = 5.40, $p < 0.001$.

The next section analyzes the modality group more deeply.

Modality Group

The results for the Modality group, in Table 7, shows that this group spent longer than all other groups in the library (t = 15.26min (SD=3.37)) but the average amount of time spent per page was much less than all other groups (t = 1.53min) and the gain in test score was less than the Cognitive Style and the Traditional group. Hence, we need to investigate number of questions such as how many pages students visited that matched their cognitive styles? and what was the average amount of time spent on these pages?.

Subjects	Total Time(min)	Total Pages Viewed	Modality Pages	% Modality pages	Time in Modality pages (min)	Time/ Modality page (min)	% Gain in Test
MR1	17.69	12	5	41.67	14.86	2.97	20.00
MR2	18.02	6	4	66.67	14.07	3.52	13.33
MR3	9.91	11	3	27.27	6.59	2.20	6.667
MR4	17.56	12	5	41.67	12.58	2.52	13.33
MR5	18.01	14	5	35.71	12.00	2.40	20.00
MR6	14.03	11	3	27.27	9.50	3.17	0
MR7	16.11	9	5	55.56	12.01	2.40	20.00
MR8	15.88	6	4	66.67	10.00	2.50	13.33
MR9	16.65	12	4	33.33	12.00	3.00	13.33
MR10	8.74	7	5	71.43	6.44	1.29	26.67
Total Mean	15.26	10	4.3	46.73	11.01	2.60	14.67

Table 7. Summary of the Modality group interaction.

In the previous section the results indicated that the students who were exposed to various types of representations (the Modality group) performed worse than the rest of the groups. This section investigates the Modality group in some detail. It examines the effect of just those pages viewed that matched students learning styles.

Table 7 shows that the mean percentage of the number of pages visited that matched the students' modality was 46.73% of the total pages viewed in the hypermedia library. The mean gain in the knowledge test was 14.67%

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and the average time spent on this subset of pages, the Modality pages, was 2.60 min. per page. If we compare this Table with the previous one (i.e. Table 4), the overall average time the Modality group spent viewing a page was 1.53 min. We can summarize this finding as follows: Students in the Modality group were exposed to various types of representations and they tended to explore the learning material using various representations and they did not stick just to the representation that matches their preferences only. They shifted from one representation to another. Furthermore, they tended to spend longer time on the pages that matched their preferences.

Synthesis

The subjects in the Cognitive Style group learned significantly better than the other three groups. Providing students with a learning environment that adapted to their cognitive styles helped them to grasp knowledge more easily than without this adaptation. Giving students the freedom to choose the modality they was had from different representations did not seem to be as an effective method of teaching. The students shifted from one representation to another, as shown by the facts that the average amount of time spent per page was much less in comparison to the other groups and the proportion of pages chosen that did in fact match their profile was less than 50%.

From this study one can conclude:-

- Students accomplish deeper understanding of a topic when it is taught in a way that matches their cognitive styles
- Providing students with a rich environment in which they can learn a topic via their chosen modality seems not to be as an effective teaching method as automatically adapting the material.

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